AFRL-IF-RS-TR-2002-198
Final Technical Report
August 2002

GLOBAL AWARENESS VIRTUAL TESTBED – DECISION SUPPORT

Frontier Technology, Incorporated

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AFRL-IF-RS-TR-2002-198 has been reviewed and is approved for publication

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
AUGUST 2002

3. REPORT TYPE AND DATES COVERED
Final Jul 99 – Mar 02

4. TITLE AND SUBTITLE
GLOBAL AWARENESS VIRTUAL TESTBED – DECISION SUPPORT

5. FUNDING NUMBERS
C - F30602-99-C-0146
PE - 61102F
PR - 2304
TA - GA
WU - B1

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Frontier Technology, Incorporated
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8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory/IFSB
525 Brooks Road
Rome New York 13441-4505

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
AFRL-IF-RS-TR-2002-198

11. SUPPLEMENTARY NOTES

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12a. DISTRIBUTION / AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 Words)*
This report summarizes the accomplishments of this effort whose primary objectives were to enhance and demonstrate Frontier Technology, Inc.'s Air Operations Center (AOC) Model in and to integrate a Space Based Radar capability with the distributed Global Awareness Virtual Test Bed (GAVTB) simulation environment. The major enhancements to the AOC Model includes the development of an HLA interface, development and integration of the embedded Decision Integrated Support Environment (DISE) module, and integration of the OPUS route planning software. A formal Design of Experiment (DOE) process was employed to develop metrics and define an experiment based on a Time Critical Targeting (TCT) scenario.

14. SUBJECT TERMS
Distributed Simulation, High-Level Architecture, HLA, Air Operations Center, AOC

15. NUMBER OF PAGES
24

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

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1.0 Introduction

This report summarizes the accomplishments of Frontier Technology, Inc. (FTI) under Contract Number F30602-99-C-0146. The primary objectives for FTI under this contract were to enhance and demonstrate FTI's Air Operations Center (AOC) Model in and to integrate a Space Based Radar capability with the distributed Global Awareness Virtual Test Bed (GAVTB) simulation environment. A formal Design of Experiment (DOE) process was employed to develop metrics and define an experiment based on a Time Critical Targeting (TCT) scenario.

The major enhancements to the AOC Model included development of an HLA interface, development and integration of the embedded Decision Integrated Support Environment (DISE) module, and integration of the OPUS route planning software. AOC Model development has followed a spiral approach. Each spiral has added new capabilities or improved on existing capabilities. The initial capability was developed for the Collaborative Enterprise Environment (CEE) under subcontract to SAIC. It should be noted that some of the development described in this report was funded by contracts other than GAVTB. These include SERENE, SimBA, and ongoing CEE support. All four efforts have been able to leverage the investments of the other programs, to the benefit of each.

2.0 AOC Overview

FTI's AOC Model is a quick-turn, medium fidelity air operations command and control (C2) simulation, including an embedded decision support module for target prosecution. AOC models aircraft, targets, weapons, routes, and Air Tasking Orders (ATO's). It runs as a real-time or constructive simulation. AOC participates in DoD standard High Level Architecture (HLA) federations, to receive aircraft and targets, and sends ATO's and revised routes. AOC also participates (concurrently or separately) in non-HLA simulation confederations receiving target detections via FTI's Automatic Target Recognition (ATR) Framework and Satellite Tool Kit (STK) from Analytical Graphics, Inc. (AGI). AOC's embedded Bayesian-network based decision support module DISE decides if time-sensitive targets are to be prosecuted and selects the best assets to assign for attack. AOC integrates the OPUS mission planner from ORCA, for generating initial and retasked aircraft routes. AOC outputs ATO's and revised routes via HLA, text files, or network socket connections. Figure 2-1 depicts the user interface.

2.1 AOC Features

Command and Control Simulation

AOC provides variable fidelity modeling and simulation of processes and objects associated with command and control (C2) tasks:

- Aircraft
- Targets
- Weapons
- Air Tasking Orders (ATOs)
- Routes

- C2 timelines

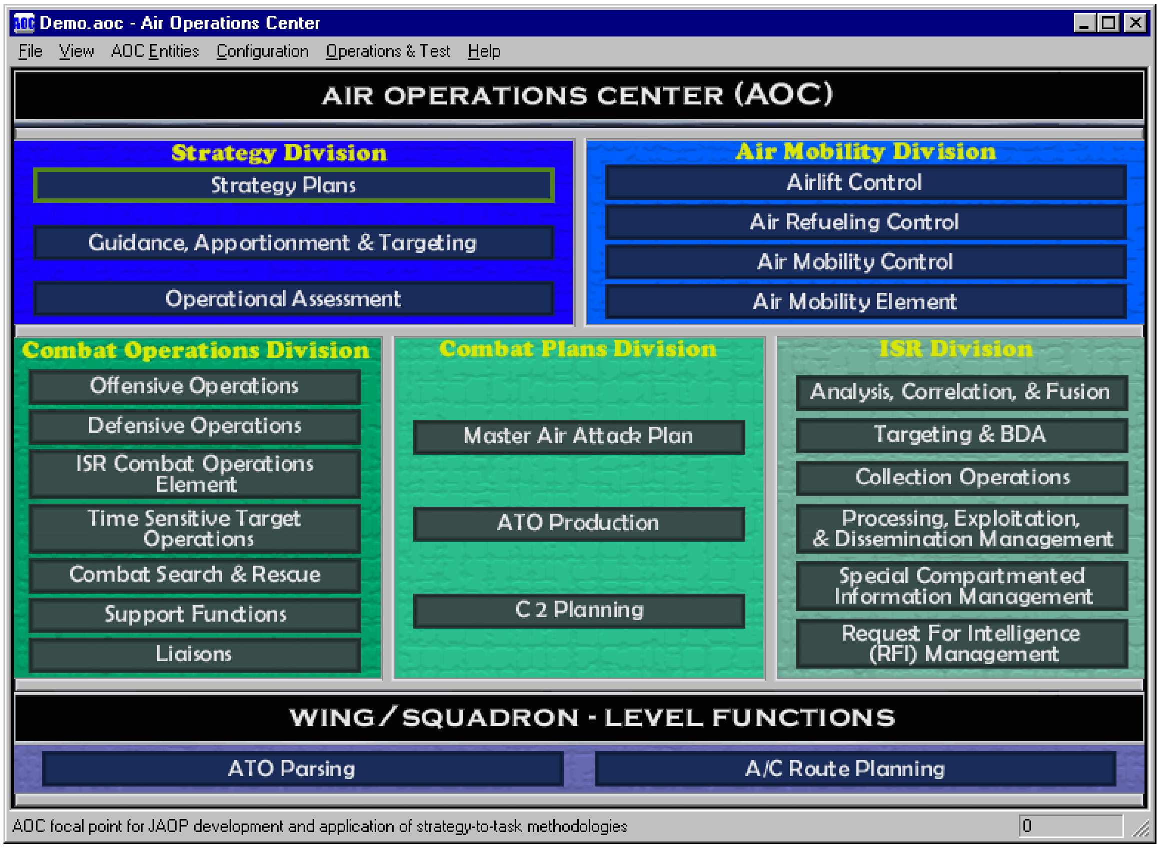

Figure 2-1 – Air Operations Center (AOC) User Interface

Decision Support

Command decision support is provided in AOC with its embedded Decision Integrated Support Engine, or DISE, which is applied to time-sensitive target prosecution decisions. DISE takes into account many decision factors, each weighted according to user preferences, to decide if a new time-sensitive target is to be prosecuted, and which available aircraft should be sent to attack it.

Mission Route Planning

Mission route planning is available to AOC through OPUS. AOC offers the flexibility of either importing OPUS routes generated a priorí, or dynamically interfacing to OPUS to create routes at run-time.

Distributed or Stand-Alone Simulations

AOC participates in various distributed simulation frameworks. AOC can participate in High-Level Architecture (HLA) distributed simulation federations that support its proprietary

Simulation Object Model (see Appendix A). AOC is also designed to concurrently (or separately) play in a non-HLA confederation that includes the Satellite Tool Kit (STK) from AGI and FTI's ATR framework.

When desired, AOC may operate in a completely independent, or stand-alone manner. An option is provided to import target detection data directly into AOC from a text file, and ATO's and revised routes may also be generated into text files.

Virtual & Constructive Simulation Modes

AOC is able to participate in both virtual and constructive simulations. Invoking AOC with a command-line string launches it in constructive mode, and starting AOC from within the typical Windows environment (with a double-click or Run command) launches it in virtual mode.

Flexible Simulation Configuration

AOC offers significant flexibility in how it behaves during simulation execution, via its many configuration options. Configuration settings may be saved, to allow AOC to be run in exactly the same controlled environment for any future simulation experiments. Users are able to choose options for:

- Simulation time (real-time, scaled real-time, or no clock)
- Connections to other simulation participants (configurable socket connections for the STK simulation confederation, or HLA settings for federations)
- Behavior of DISE decision-making (factor weights),
- DISE results usage (always use DISE selected assets, wait for human consideration and selection)
- Routing (stick-routes, pre-generated OPUS routes, dynamic OPUS routes)

Traecability

AOC offers many options and tools for displaying the progression of simulation sessions. These include multiple data views to review intel at various stages of C2 processing, such as initial target lists from an initial ATO shred, current updated nominated target lists, and nominated target-weapon pairings. Additionally, the user is able to review logs of both the HLA and non-HLA subsystems, as well as all internal events occurring during a session.

2.2 AOC Upgrades for GAVTB

The following sections describe the major upgrades to AOC performed under the GAVTB contract.

2.2.1 HLA interface

AOC Model offers the capability of participating in HLA federations. The HLA interface (Figure 2-2) in AOC Model supports publishing and subscribing to Aircraft and Target objects, and publishing ATO and ATO_R interaction messages which contain Aircraft routing information based on Air Tasking Orders and revisions to such. AOC Model is user-configurable in terms of how it drives or reacts to simulation time as managed by HLA: it may be configured to be constrained by simulation time, it may be configured to regulate simulation time, neither, or both. While participating in GAVTB experiments and demonstrations, AOC is generally configured to Subscribe to Aircraft and Targets, and to Publish ATO and ATO_R interaction messages. Additionally, AOC Model was configured to both be Constrained and Regulating with regard to simulation time management.

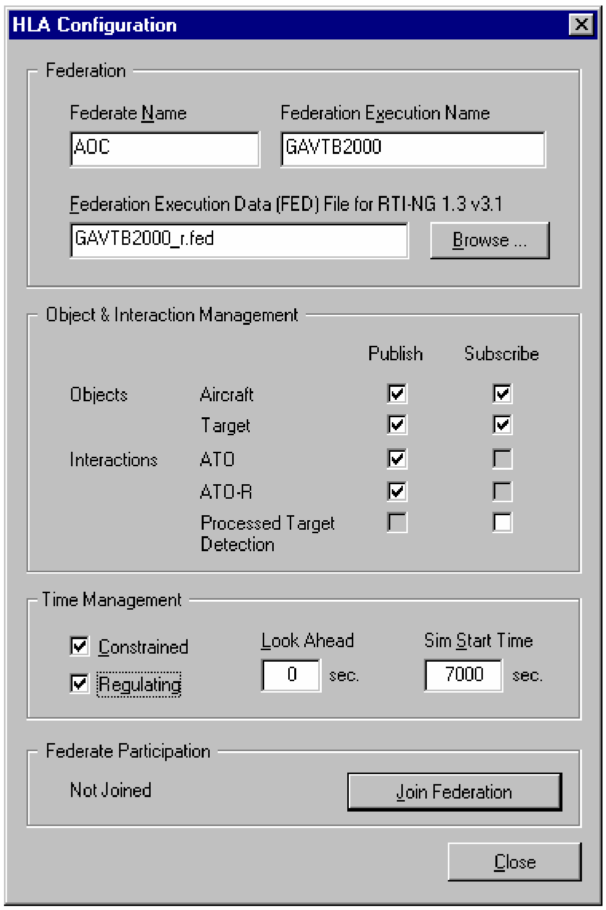

Figure 2-2 Configuration of AOC Model's HLA Interface

In addition to the necessary description of data and messages provided by the simulation Federation Object Model (FOM), successful participation in an HLA federation often requires an agreed-upon protocol of events that define federates' behaviors. AOC Model's HLA interface design incorporates such an agreed-upon protocol; it is referred to as the Synch Point Protocol. Synch Point Protocol insures that AOC Model does not advance in simulation time until it's been notified that all the other federates it requires have joined, and that it has received a particular synch point which triggers creation and dissemination of the Initial ATO. For GAVTB, the only required federate is Suppressor. Figures 2-3 and 2-4 illustrate the event sequences in AOC and Suppressor federates and the HLA Run-Time Infrastructure (RTI) which embody dissemination of the Initial ATO (the ATO interaction), and revisions to ATO routes that occur thereafter (the ATO_R interaction).

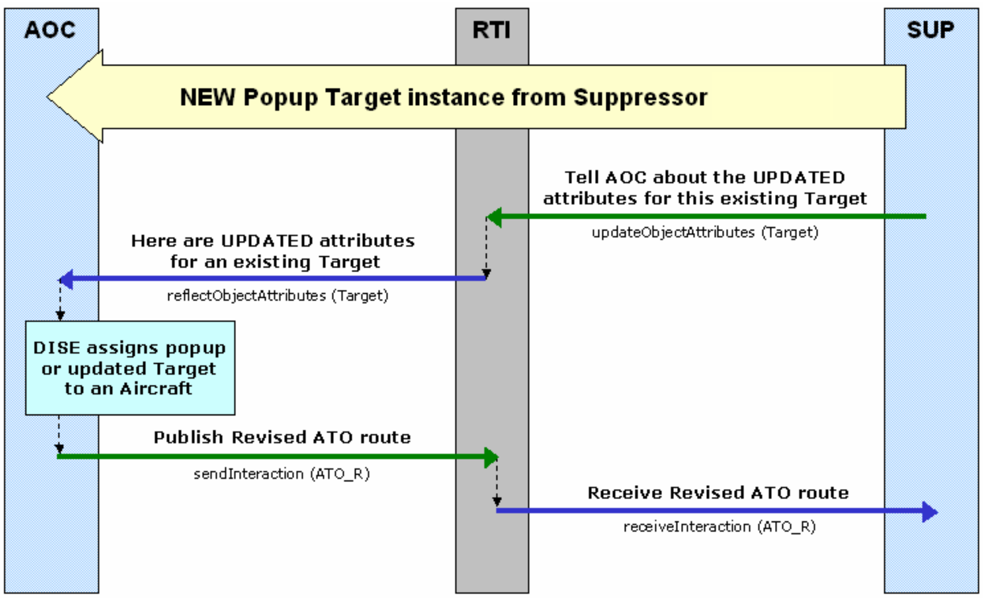

Figure 2-3. Event sequence for dissemination of Initial ATO by AOC in GAVTB

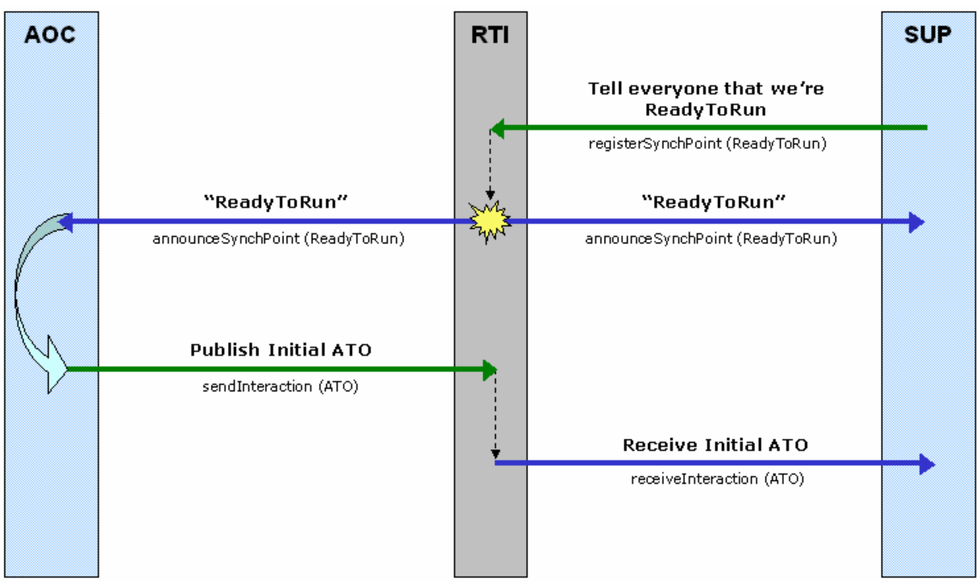

Figure 2-4. Event sequence for dissemination of revised ATO (ATO_R) by AOC

2.2.2 Decision Integrated Support Environment (DISE)

In describing the tasks performed by the AOC, Air Force regulation AFI 13-1 AOC states "The prosecution of Time Sensitive Targets (TSTs) is one of the most challenging tasks of the

AOC's Combat Operations Division (COD)". Therefore, when modeling the functions of the AOC, we initially focused on the operations involved with the dynamic retasking of aircraft during the execution of the established ATO based on new intelligence from ISR sources … in essence the Time Critical / Sensitive Target (TCT / TST) challenge. We have developed and embedded a Bayesian Network (BN) decision support tool within AOC. Bayesian Networks are an extension of Bayesian decision theory; a technique used extensively in business to identify the "best" decision given probabilities of events or factors.

In applying BN's to the TCT / TST issue, we focused on two important decisions. The first one consists of deciding whether to nominate a target. If the target has been nominated, the second part is deciding the appropriate aircraft to attack the target.

Once a target has been detected, it is not automatically nominated for attack. The decision of whether to nominate a TCT depends on several factors:

- Classification Confidence-represents the level of certainty that the target has been correctly identified
- Time Criticality of TCT-how "critical" it is to attack the target depending on its operational status
- TCT Type-different types of TCTs will have different priorities
- TCT Target Priority-dependent on the TCT's time criticality and its type
- TCT Mission Priority-dependent on the classification confidence and the TCT priority
- Priority of Lowest Assigned Mission-represents the priority of the least urgent mission which has already been assigned

The two predominant factors that influence this decision are the priority of the new mission (to attack the newly spotted target) and the priority of the lowest mission that has already been assigned. These two priorities will be compared and the target will be nominated only if the priority of the new mission is higher than that of the lowest assigned mission.

Once a new target is nominated, aircraft must be reassigned to attack it. Because there are many aircraft available, each aircraft must be considered and the most suitable will be chosen. This will depend on the following:

- Fuel Level-expected amount of fuel in aircraft at completion of reassigned mission
- Type of Weapon-available weapons on board aircraft
- Probability of Survival-based on the selected route to the new target
- Potential Collateral Damage-amount of damage incurred on TCT surroundings
- Timeline Status of TCT-how soon it must be attacked, depending on its operational status
- Time to Target-aircraft's distance (in minutes) from the TCT
- Current Mission Priority-priority of the mission to which the aircraft is currently assigned
- TCT Mission Priority-determined when the target is originally nominated
- Possible Reassignment-represents whether it is possible to reassign the current target assigned to this aircraft
- Aircraft Retasking Availability-represents any factor not taken into account by the model, including commander override

In this decision, all of the factors listed above will directly influence the decision. However, the relative importance of each factor will vary for different TCTs and different operational situations. For example, for many missions Probability of Survival (Ps) may be the most important consideration, but in a mission prosecuting a TEL thought to be preparing to launch nuclear weapons time to target may indeed become the highest priority. To take this into account, a weight is associated with each factor. Therefore in the case above, the weight specified for Ps will be lower in the case when a nuclear TEL is nominated.

Within AOC, the Bayesian Decision networks used to make the above decisions are modeled in a COTS tool called Netica. Decision networks can be represented as graphs with nodes and links. The nodes represent the different factors that are included in the decision process; the links represent the causal relationship between the nodes. Three types of nodes are used in decision networks:

- Nature Nodes - these nodes are factors determined by nature, such as the fuel level in an aircraft. Nature nodes have different states, which influence the decision being made. Nature nodes are in the shape of an oval or a white rectangle in the networks below.
- Utility Nodes - the value ("goodness") of each combination of the states contained in the nature and decision nodes. Utility nodes are seen in the shape of diamonds.
- Decision Nodes - used to recommend / make the "best" decision. Decisions are measured by the value of each state contained in the node. The state with the highest value indicates the best decision. A decision node is represented as a blue rectangle.

2.2.3 ORCA PLANNING AND UTILITY SYSTEM (OPUS)

The ORCA Planning and Utility System (OPUS) is an interactive military aircraft mission planning tool. Its autorouting and analysis functions make OPUS useful for mission effectiveness and survivability studies. The system performs force level planning as well as generating terrain aware threat avoiding individual sortie routes. OPUS optimizes in the target area including sensor pointing and weapon release maneuvers. OPUS includes utility functions for manipulating terrain information, threat data, weapon characteristics, vehicle performance data, and route plans. Validated performance and threat data to run the model is available from ASC/ENS at Wright-Patterson Air Force Base in Ohio.

OPUS is used for both operational and analytical applications. The incorporation of functionality to parse Air Tasking Orders (ATO) has made OPUS a valuable tool for the USAF Combat Air Force which has licensed it for use at every operational Wing. This functionality (sometimes referred to as the Hill ATO Defragger) is available in OPUS version 2.47 and later.

Features of OPUS include:

- An autorouter that produces threat avoiding, goal seeking, terrain aware routes for both conventional and Low Observable (LO) Radar Cross Section (RCS) signatures.
- New threat analysis techniques result in route generation speeds far faster than traditional time step / ray trace approaches.
- A variety of figures of merit for attrition analysis and a documented C3I model. A SAM engagement model and an AI endgame model are implemented for both Monte Carlo simulation and static attrition analysis.
- Automatic planning of weapon releases that conform to common tactics for various weapons including standoff, gravity, PGM, and interdependent platform / smart

weapon planning. Eliminates the need for manual weapon release sequence placement.

- Automatically plans weapon release maneuvers including release heading constraints, straight and level times, damage assessment, navigational update, and offset aim point imaging.
- Support for importing routes from AFMSS and exporting OPUS routes and threat laydowns to AFMSS.
- Exports routes in the Enhanced Air Defense Simulation (EADSIM) format.
- Multiple resolution terrain model limits amount of terrain data required without sacrificing resolution in critical areas. OPUS models terrain avoidance as well as defensive and offensive terrain masking effects. OPUS can develop TF/TA routes.
- Performs automatic search planning through relocatable target areas.
- Allows optimization and analysis of event driven signatures (e.g., bomb bay doors opening, onboard jammers).
- The ability to import and export Air Tasking Orders in USMTF ATO95 and ATO98 formats.

FTI has completed integration of OPUS into AOC. This was accomplished by embedding the OPUS application programming interface (API) directly into the AOC code. The AOC code was modified to provide the data required by OPUS, and to utilize the resulting OPUS output, thereby making OPUS usage transparent to the user. OPUS is used within AOC to perform three primary functions:

- Generate initial aircraft routing. The ATO produced by AOC contains detailed routing information for all aircraft (often provided at the wing or squadron level in the real world). By using OPUS, realistic threat avoiding, terrain aware routes can be rapidly generated, taking full advantage of each aircraft's unique signature and weapon delivery requirements.
- Generate rerouting alternatives for TCT prosecution. As discussed above, when the DISE module determines that a new target is critical enough to modify the existing ATO, the next step is to evaluate the alternatives for prosecuting that target. OPUS is called to prepare threat-avoiding routes to the new target for all aircraft under consideration. OPUS then provides time to target based on realistic rerouting considerations (not just stick routes to the target). Opus also provides probability of survival and expected fuel status at mission completion. This information is essential to allow DISE to select the best aircraft for reassignment.
- Input and output ATO's in real world formats. The OPUS ATO parser is has the ability to import and export Air Tasking Orders in USMTF ATO95 and ATO98 formats. This enables ATO's produced by real world systems such as TBMCS to be used easily within the AOC simulation framework.

3.0 FTI Support for GAVTB 2k Experiment

The GAVTB 2k experiment was designed to demonstrate the emerging capabilities discussed above, as well as validate the GAVTB virtual test bed reconfigurable distributed simulation concept. As figure 3-1 shows, the GAVTB framework was expanded to include several additional components, including the SST SBR, a high fidelity space based radar model from Philips Labs, and SIRE / CART human factors models.

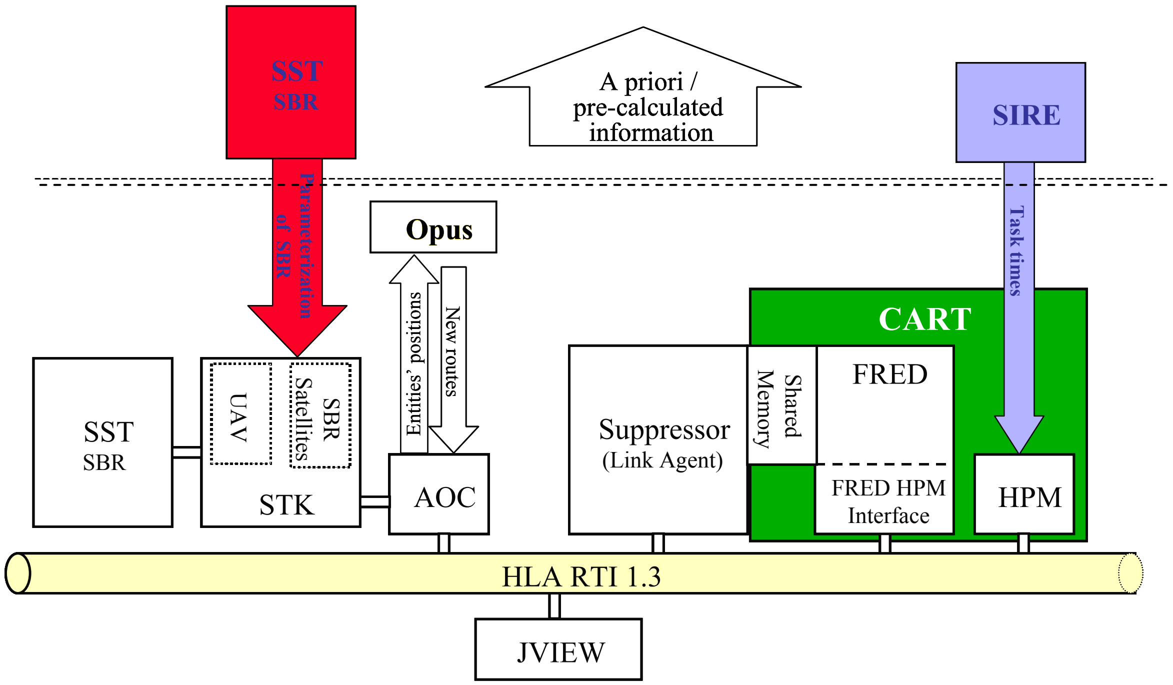

Figure 3-1 GAVTB 2k Experiment Components

The GAVTB 2k experiment included both a real time virtual demonstration and constructive simulation. Figure 3-1 illustrates the layout of components in the virtual demonstration, using the HLA RTI as the backbone for connectivity. The key to making this federation work was getting the AOC and Real Time Suppressor to communicate via the RTI. This was accomplished by a joint effort from FTI and SAIC. FTI was then responsible for the interfaces from AOC to STK, OPUS, and SST. SAIC handled the interfaces to FRED, CART and SIRE. In the constructive runs, STK, OPUS and AOC communicated with Suppressor via a resource agent developed by SAIC, using the Knowledge Konnect workflow.

3.1 ISR System Simulation

ISR system modeling for the GAVTB 2k experiment was provided by FTI's Surveillance Analysis and Simulation Environment (SASE) Module. The core of the SASE module is a COTS tool, the Satellite Toolkit (STK) developed by Analytical Graphics, Inc. (AGI). This core, and enhancements developed by FTI, allowed the simulation of a space-based radar constellation and airborne ISR assets, and to analyze the performance of these ISR assets in detecting ground based targets, with focus on TCT operations simulation. SASE is designed to interface with several AOC components, including the aircraft routes generated by the OPUS module discussed above and the DISE module integrated in the AOC Module.

3.2 SST SBR GMTI Model Integration

The overall SASE approach to ISR representation is based on the premise of variable fidelity modeling. Under this approach the low to medium fidelity sensor and communications tools included with STK are used whenever they provide an adequate representation for the given analysis task or experiment underway. When higher fidelity tools are required, the SASE environment provides an interface to bring them into the distributed simulation. An example of this approach was demonstrated in the GAVTB 2k experiment, when the high fidelity SST GMTI radar simulation tool was linked in to provide detection data for a given satellite, while STK's radar model was used for the remaining satellites.

SASE modeled the entire SBR satellite constellation within STK. The radar defined in STK was an abstraction of the SST SBR radar. The higher fidelity SST SBR simulation was used for a single satellite, chosen a priori. SST took control of this satellite, and used its SBR model to determine probability of detection, sensed position and velocity. This data is then passed back to STK. STK in turn passed this data to the AOC, along with probability of detection messages from other satellites in the constellation. The ATR algorithm in the AOC processed all these detection messages in a same manner, making the inclusion of SST transparent to the AOC.

As shown in Figure 3-1, SST and STK communicate with the GAVTB RTI via the AOC module. The AOC module communicates with the RTI and STK, and STK then shares data with SST. The data required from STK by SST is target position and velocity. The AOC module receives aircraft and target position and velocity updates from Suppressor via the RTI at a 1 hertz rate. The AOC subscribes to these, and passes the data on to STK via SASE's AOC-to-STK module. An additional interface was developed using STK's Connect module, to get target position and velocity updates as well as satellite position from STK to SST, as well as to return probability of detection, sensed position and velocity calculated by SST.

3.3 Design of Experiments (DOE)

FTI tailored and applied a formal DOE process to design the experiment used to demonstrate the software configuration discussed above. This process included the following steps:

Step1) Define the problem (analysis question to be answered). Prosecution of Time Sensitive/Time Critical Targets (TCTs) was selected as the problem to be analyzed, as this continues to be a major deficiency in the C3ISR process. To improve the prosecution of TCTs, the AOC needs to improve its process to make timely and accurate decisions related to the receipt and interpretation of real-time ISR data. Additionally, real time / Near-real time robust and accurate ISR data is needed to support the timely prosecution of TCTs.

Specifically, the question to be addressed was: What is the Military Utility / Value of SBR in re-tasking ground attack assets in-flight to prosecute TCTs? The Korean Peninsula was selected as the theater of interest.

Step 2) Define the measures of effectiveness (MOEs). Two types of MOEs were considered:

- Mission effectiveness measures, including number of TCTs negated, timeliness of TCT negation, and overall value of target set engaged.
- Blue force utilization metrics, including aircraft lost and sorties flown.

Step 3) Identify the control variables (those within the designer's control). Control variables considered focused on blue force structure variables, including:

- ISR assets available
  - SBR Constellation Performance
    - Number of SBR satellites,
    - Deployment Altitude,
    - Sensor Capabilities
  - Number of UAVs, Their SAR Performance, Hi / Low Altitude Mix, etc., Surveillance Routes
  - Other ISR assets (JSTARS, AWACS, DSP / SBIRS Hi-Lo, Other A/C, etc.)
- Blue strike aircraft deployment:
  - Number of aircraft on CAP, CAP locations
  - Number of aircraft on ground alert, airbase locations
  - Munitions loadout
- CONOPS / ROEs for nominating targets for attack and decision process for committing assets
- Timeline Implications
  - Comm. Network latency
  - Information Processing latency
  - Decision timelines
- Accuracy of ATR / Target Nomination Process

Step 4) Identify the external variables (those outside the designer's control). External variables considered included:

- Theater of Interest: The Korean Peninsula was selected.
- Threat laydown:
  - SAM types and locations. Although this experiment was strictly a capability demonstration, and not intended to produce validated analytic results, the use of a "realistic" laydown was considered important to provide "realistic" route re-planning dynamics and implications on attack timelines.
  - Red Aircraft Patrols. For simplicity we assumed Air Superiority for this experiment
- Target locations & value priorities
- TCT types, timelines, and movement / deployment locations

Step 5) Design the layout for the experiment, and construct the case matrix. Since this was a capabilities demonstration, the desire was to keep the scenario fairly simple, while still highlighting the types of analyses that are possible with this GAVTB configuration. The following entities were included in the scenario:

- 4 Blue strike aircraft, prosecuting an ATO versus fixed targets.
- 0-2 Blue strike aircraft on ground alert
- Blue ISR assets, including an SBR constellation, and 2 global hawk UAVs.
- A Red bridge, which is not on the initial target list, but becomes time critical when an armored column is detected advancing toward it.
- Red TBM TEL, location initially unknown to blue forces (pop-up target)
- Red SAM threat systems, at known locations, allowing OPUS to plan threat avoidance routes when possible.

Four strike aircraft are prosecuting their assigned missions. ISR assets detect armored forces northwest of Ich'on approaching a bridge on the Imjin-gang river. The bridge is declared a TCT and targeted for preemptive strike to deny crossing of Imjin-gang. The AOC must select a single ship strike package to accomplish the mission, from among the four airborne aircraft or the two aircraft on ground alert. The choice of aircraft depends on time to target, weapon suitability, sufficient fuel, and the priority of the currently assigned target. ISR assets (SBR/UAV) then provide information on the second TST; a TBM TEL located southwest of Sariwon. AOC again must re-plan the flight path of one or more strike aircraft or ground alert aircraft.

Case Matrix: In this step, we selected parameters to vary from among the control and external variables discussed above. We also determined the range over which to vary the selected parameters. Again, the goal was to demonstrate capability, so only a subset of the possible control and external variables were chosen, and the range of variation was minimal to keep the case matrix within the scope of the effort. Figure 3-2 shows the selected parameters. The primary variant was the SBR constellation, varying from no SBR, to a partial 12-satellite capability, to a full 36-satellite constellation. Other variations included running the scenario with and without ground alert aircraft available, and changing the time required to assimilate process and disseminate intel data (the sensor to decision maker to shooter timeline). An additional variable was the criteria used to weight factors used by the DISE decision support module. These factors include time to target, current mission priority, survivability, and weapon suitability, among others. Assigning different priorities to these factors can influence aircraft selection. This resulted in a 24 case matrix. The constructive runs were performed prior to virtual demonstration.

Variables for '00 Exp.	Level 1	Level 2	Level 3
SBR Architecture			
# of Satellites	None	Few	Many
Aircraft on CAP?	No	Yes	
Timeline Latency	Slow	Fast	
Decision Criteria Priority	Case 1	Case 2	

Figure 3-2 Variable ranges for GAVTB 2k experiment

Step 6) Conduct the experiment, generate results. As noted earlier, the constructive cases were run using the Knowledge Konnect workflow, and aircraft route data was passed from AOC to Suppressor via resource agents. FTI components played the following roles in the demo:

- AOC Model: The AOC coordinated generation and dissemination of the initial ATO, consisting of routes for four strike aircraft. AOC received ISR data from STK, and performed rudimentary ATR processing to declare new TCTs, triggering the DISE module. New aircraft routes were then passed to Suppressor. Communication with Suppressor was done via Resource Agents in the constructive runs, and HLA in the virtual demo.
- OPUS: OPUS was used to generate threat avoiding, terrain aware initial routes for the strike aircraft, as well as potential reroutes for all aircraft to the newly detected TCTs. OPUS also provided survivability and fuel usage estimates for the reroutes to DISE.

- DISE: DISE performed two functions. As soon as the AOC ATR algorithms classified a new TCT, DISE determined if it was high enough priority to modify the existing ATO for immediate attack. DISE then assessed the best aircraft to assign to the new TCT, based on time to target, survivability, current mission priority, and other factors.
- SASE: The GAVTB 2k experiment leveraged FTI's ongoing development of SASE (Surveillance Analysis and Simulation Environment). The core of SASE at this time is STK, a COTS software tool. STK was used to model the ground targets, surveillance aircraft, satellites, and sensors. Attack aircraft routes were included for visualization. Sensor detections of TCTs were sent to the AOC via SASE Connect modules. Another important aspect of SASE exercised in the GAVTB 2k experiment was the ability to link to higher fidelity external simulations as required. In this case, an interface was developed to Philips Lab's SST SBR GMTI model. SST is a single sensor model. The full satellite constellation was propagated in STK. As a selected satellite approached the theater, ephemeris data was transmitted to SST, along with target data. SST then simulated radar performance for that satellite, sending detection data back to STK. STK passed this data along with detection data from the other satellites to the AOC.

Step 7) Analyze the data, generate information based on the results. All results from this experiment should be treated as notional. Scenario elements, blue and red system performance parameters, and concepts of operation employed were not validated or approved by any government source. The rigor required to define a validated scenario, as well as the resources required to generate statistically meaningful results were well beyond the scope of this capabilities demonstration. Further, the experiment was run at the unclassified level, which precluded use of actual weapon system performance parameters. The goal of the experiment was to demonstrate the emerging capabilities of the GAVTB distributed simulation environment, and the scenario and data used were certainly sufficiently "realistic" for that purpose.

While the results must therefore be considered notional, one of the capabilities to be demonstrated was the robust process in place for data analysis and generation of military utility metrics. To that end, FTI's I-CAIV tool and process was used to archive and organize the raw data, convert results for each MOE into a utility score, and produce a notional CAIV (Cost As Independent Variable) plot. The I-CAIV tool for the GAVTB 2k experiment was structured to show the cost – benefit relationship for the three SBR options considered in performing the TCT mission.

The I-CAIV tool developed for GAVTB has four main capabilities. The first of these is the prioritization of the MOEs. This is accomplished in the tool via an automated AHP engine, allowing any number of voters to enter pair wise assessments of the relative priorities of each MOE. The I-CAIV tool then uses these results to produce a relative weighting for each MOE. Furthermore, the tool allows the user to assign voters to various groups to see how the weightings (and the end results) vary when different voter groups are considered. Figure 3-3 shows the six MOEs measured in the GAVTB experiment, and the relative MOE prioritization screen from I-CAIV. As can be seen, participants in the GAVTB MOE prioritization exercise rated preventing TBM launches as the highest priority, followed by minimizing blue aircraft losses and preventing the armor column from crossing the bridge.

MOE	All Voters
TBM Launches Prevented	40.4
Blue Aircraft Lost	19.7
Bridge Crossing Prevented	19.7
Value of Targets Prosecuted	9.5
TELs Killed	8.5
Blue Sorties Flown	2.3

Figure 3-3 I-CAIV MOE prioritization

The second main capability of the GAVTB I-CAIV tool is the ability to convert raw simulation results for each MOE into a utility score. This is done by creating a tailored utility function for each MOE. Figure 3-4 shows an example of a utility function in I-CAIV. This example is for the MOE representing the overall value of the targets negated. Each target in the scenario, including the TCTs, had a priority value assigned to it. This MOE is the sum of the priority values for each target negated. For each set of initial conditions (variables in the run matrix), I-CAIV accesses the Suppressor results for targets negated, to determine the raw value of this MOE. Then a utility function is used, converting the raw score to a utility value between 1 and 10. The shape of the utility function used, and the objective and threshold values selected can have a dramatic impact on the utility evaluation of the alternatives under consideration. Therefore, the generation of utility functions is usually done in concert with the user and all stakeholders in the process. Two common types of utility curves are shown in the example; a linear function and an S-curve. The S-curve provides a more gradual change as the objective or threshold values are approached. Other types of functions, including logarithmic, exponential and step functions can be employed. The GAVTB 2k I-CAIV used linear functions for all MOEs.

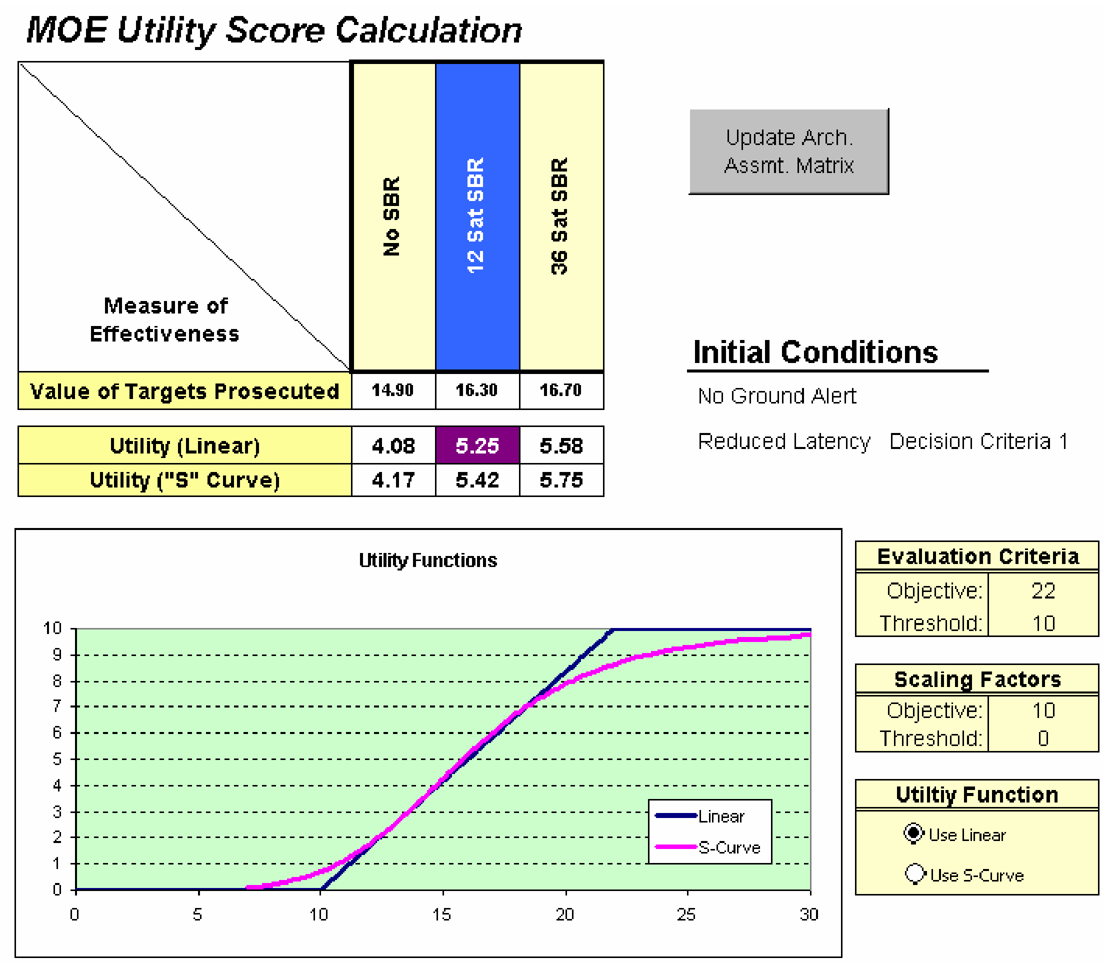

Figure 3-4 I-CAIV utility calculation

After the raw data for each set of initial conditions for a given MOE has been converted into utility scores, the utility scores are rolled up to produce utility values for each alternative under consideration for each MOE. Figure 3-5 illustrates this for this same MOE. At this point, initial conditions can be weighted relative to each other, so that more important scenario variations have greater impact on the rolled up utility value. For instance, if the user feels that ground alert aircraft will not likely be available for this type mission, he could weight those cases lower (or zero). In the GAVTB 2k I-CAIV, all initial conditions were weighted equally.

Return

Value of Targets Prosecuted

		Initial Condition Importance	Architecture Alternatives: No SBR	12 Sat SBR	36 Sat SBR
No Ground Alert	Baseline Latency Decision Criteria 1	1	3.25	1.31	2.54
	Baseline Latency Decision Criteria 2	1	3.25	4.58	5.17
	Reduced Latency Decision Criteria 1	1	4.08	5.25	5.58
	Reduced Latency Decision Criteria 2	1	4.08	5.25	5.58
With Ground Alert	Baseline Latency Decision Criteria 1	1	3.25	8.58	7.04
	Baseline Latency Decision Criteria 2	1	3.25	8.58	7.04
	Reduced Latency Decision Criteria 1	1	8.58	8.58	9.58
	Reduced Latency Decision Criteria 2	1	8.58	8.58	9.58
		Weighted Average	4.79	6.34	6.52

Figure 3-5 I-CAIV utility rollup for a single MOE

The third main capability of the GAVTB I-CAIV tool is the generation of an interactive CAIV profile. After all MOE data is entered into the I-CAIV tool, the utility functions convert the raw values to a common scale, as described above. This provides an assessment of how well each alternative performed for each MOE. These scores are then multiplied by the appropriate weight for each MOE, as shown in Figure 3-6, to produce an overall utility score for each alternative.

Architecture Assessment

Review / Edit MOE Prioritization

Measures of Effectiveness	MOE Importance	Architecture Alternatives: No SBR	12 Sat SBR	36 Sat SBR
TBM Launches Prevented	40.4	0.0	0.0	7.1
Blue Aircraft Lost	19.7	10.0	9.4	8.0
Bridge Crossing Prevented	19.7	5.0	7.9	9.1
Value of Targets Prosecuted	9.5	4.8	6.3	6.5
TELs Killed	8.5	0.0	0.0	3.9
Blue Sorties Flown	2.3	5.8	5.5	5.5
	Weighted Average Utility Score	3.5	4.1	7.3

Figure 3-6 I-CAIV utility rollup for all MOEs

Combining this score with cost data, the tool produces the CAIV profile, as shown in Figure 3-7. The CAIV profile provides a graphic comparison of the relative utility of the alternatives, as well as the cost associated with each alternative. As Figure 3-7 shows, in the GAVTB 2k experiment, the 12 satellite constellation produced only marginal increase in utility. The full 36 satellite constellation achieved a significantly higher utility, but at a higher cost. Again, the numbers shown here must be regarded as notional. The cost numbers shown have no basis in fact whatsoever, and were merely added to illustrate the functionality of the I-CAIV tool. No conclusions should be drawn from this data.

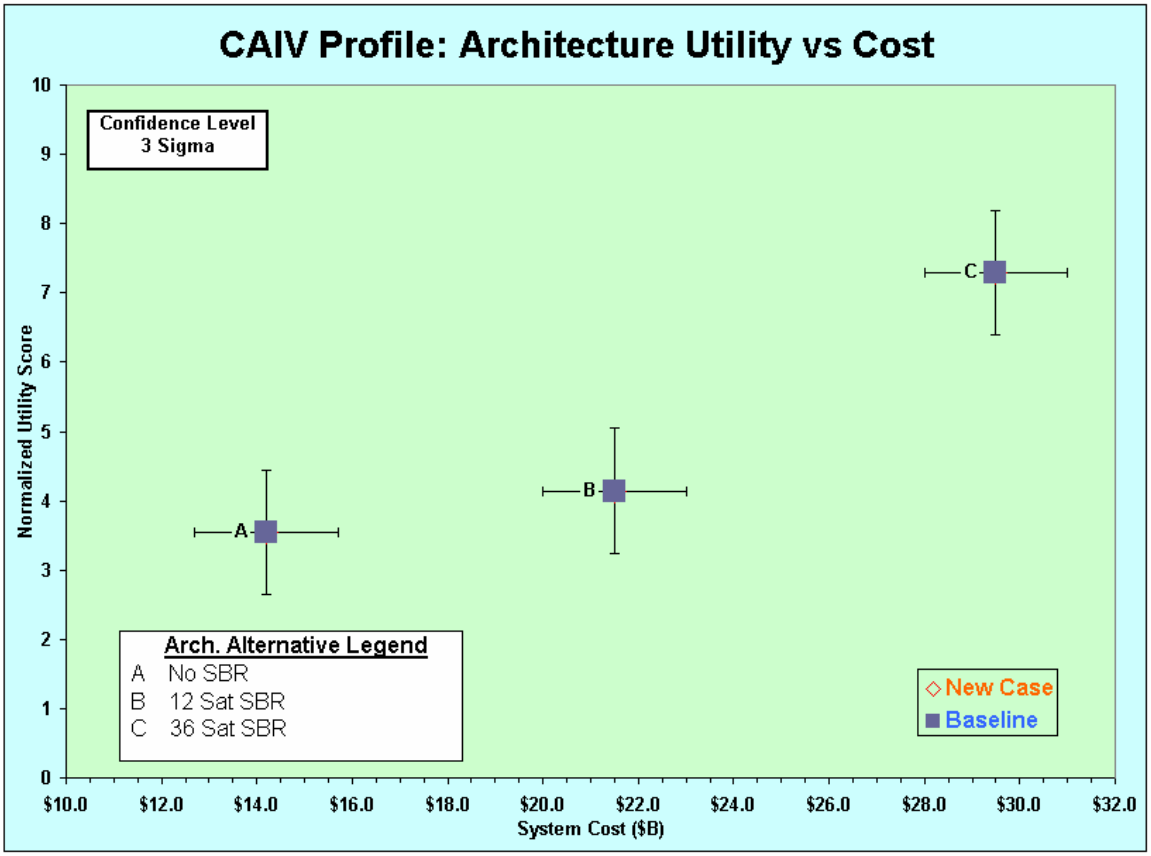

Figure 3-7 I-CAIV interactive CAIV profile

Note that this profile is interactive, in that the user can select any single MOE (or group of MOEs), or MOE prioritization and see the results instantly change to reflect only the selected MOE(s). Similarly, the user can select any subset of initial conditions, and see the impact on final results. Figure 3-8 shows an example of this, where the user has selected to see the utility results based only on the slower timeline latency. These results are shown in orange on the figure, while the baseline case (all conditions) remains in blue for comparison. In this case, it can be seen that the importance of timely SBR data to the AOC is even greater, since the longer AOC processing compresses the time available to react to TCTs. Under these conditions, even the partial constellation provides a significant performance improvement over no SBR at all.

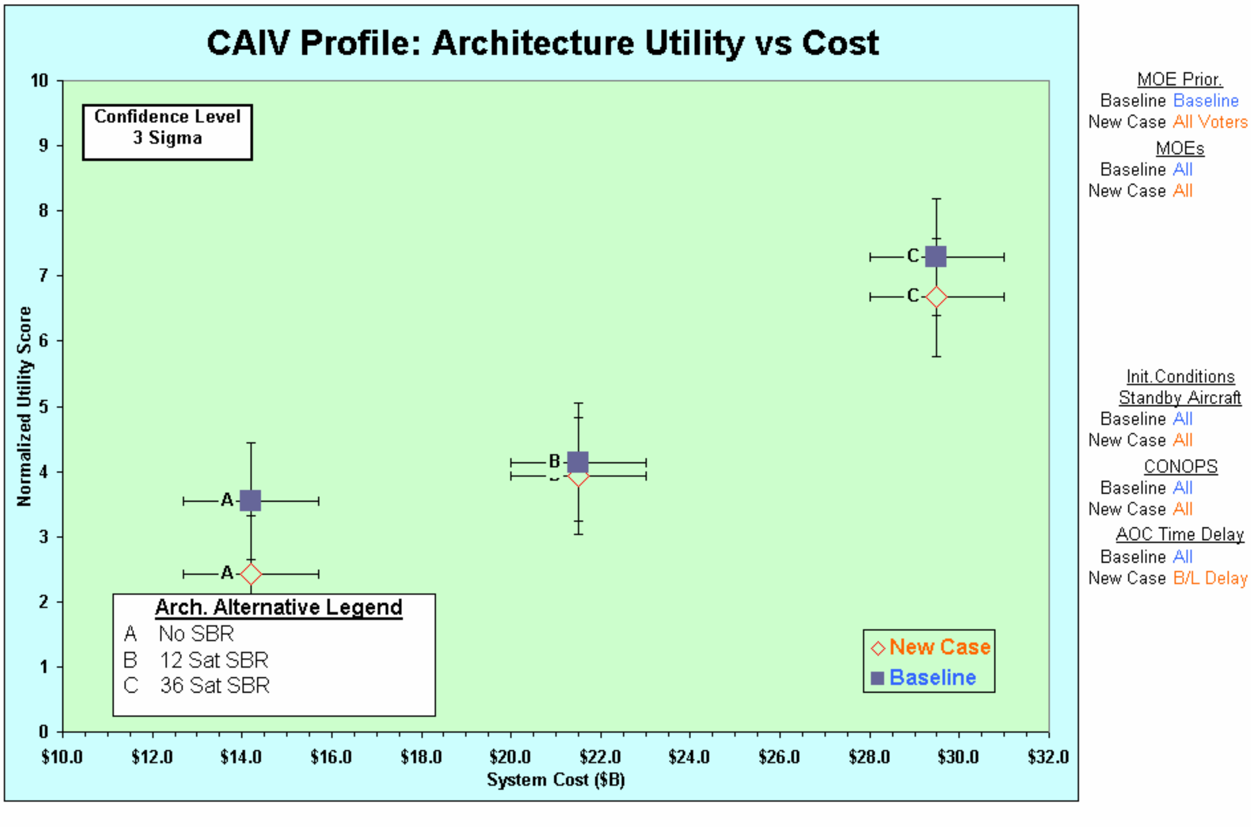

Figure 3-8 I-CAIV interactive CAIV profile, showing sensitivity to initial conditions

The fourth capability of the GAVTB I-CAIV tool is the generation of a three dimensional CRAIV trade space. CRAIV stands for "Cost and Risk As Independent Variables". This trade space is created by importing risk data for each concept, to give the decision maker a robust 3 dimensional view of the alternatives, as shown in Figure 3-9. As with cost values shown, the risk values shown here have no factual basis, and were inserted to demonstrate the capability.

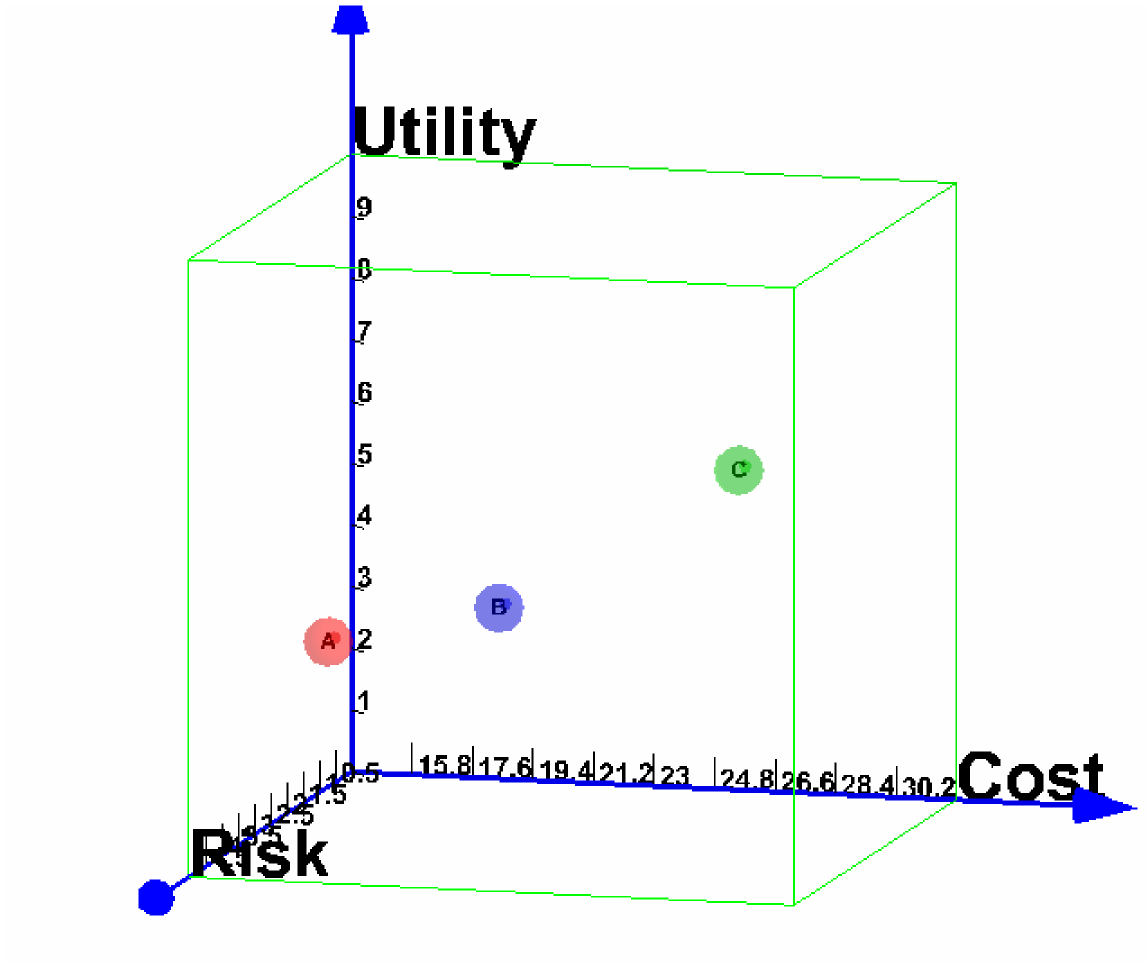

Figure 3-9 I-CAIV three-dimensional CRAIV profile

4.0 Conclusion

In conclusion, we feel that this effort in support of the GAVTB effort was very successful. Significant new capabilities were added to existing components, new components were created, and links to external components were developed. The GAVTB 2k experiment provided a valuable forum to exercise the new components and links, as well as demonstrate the types of analyses that the GAVTB framework can provide.